# SPECIFIED GAS EMITTERS REGULATION

# QUANTIFICATION PROCESS FOR WASTE HEAT RECOVERY PROJECT - STREAMLINED

## SEPTEMBER 2007

Version 1

Alberta ENVIRONMENT

ALBERTANS & CLIMATE CHANGE

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The information provided in this document is intended as guidance only and is subject to revisions as learnings and new information comes forward as part of a commitment to continuous improvement. This document is not a substitute for the law. Please consult the *Specified Gas Emitters Regulation* and the legislation for all purposes of interpreting and applying the law. In the event that there is a difference between this document and the *Specified Gas Emitters Regulation* or legislation, the *Specified Gas Emitters Regulation* or the legislation prevail.

**Note To Waste Heat Recover Project Developers:**

Two versions of the Waste Heat Recovery Protocol have been developed in recognition of two groupings of projects. The project types covered under this first protocol represent the streamlined projects which typically include only one entity or site. For these projects, waste heat from one operation is used to supplement the heat requirement at another point. As such, there is no impact to the operation of the unit where the waste heat is being utilized.

The second protocol covers a broader range of projects that may include multiple entities and multiple sites. Further, more complex heat and power generation configurations from multiple sources are contemplated. Under this scenario, there may be changes to the operation of the unit where the waste heat is being utilized.

To illustrate the parallels between the two protocols, numbering and naming of sources and sinks remains constant across the two protocols. As such, it may appear that there are gaps in the numbering of sources and sinks in the streamlined protocol. However, these gaps correspond to sources and sinks considered as part of the broader protocol.

Any comments, questions, or suggestions regarding the content of this document may be directed to:

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# 1.0 PROJECT AND METHODOLOGY SCOPE AND DESCRIPTION

## 1.1 PROTOCOL SCOPE AND DESCRIPTION

This quantification protocol is applicable to the quantification of direct and indirect reductions of greenhouse gas (GHG) emissions resulting from the implementation of streamlined waste heat recovery projects. The protocol quantifies the emission reductions from the avoidance of fossil fuel consumption resulting from the capture and utilization of heat that is currently being wasted. The waste heat recovery may be transferred into the project site where it is utilized, or may be recovered and used within the project site. **FIGURE 1.1** offers a process flow diagram for a typical project.

The waste heat recovery protocol does not prescribe the configuration of the scheme. Rather, this protocol serves as a generic 'recipe' for project proponents to follow in order to meet the measurement, monitoring and GHG quantification requirements. The project must achieve some level of fuel savings by capturing and utilizing waste heat.

The waste heat recovery protocol quantifies emissions reductions on the basis that the heat demand being offset was being achieved through fossil fuel combustion, either on-site or off-site. Thus, the starting point for all quantification is the heat load of the project and how this is being achieved. **FIGURE 1.2** offers a process flow diagram for a typical baseline configuration.

The boundary of the waste heat recovery protocol encompasses the recovery, distribution and utilization systems, which may cross site boundaries. Further, the utilization systems are defined as those within the impacted unit, i.e. equipment, processes, facilities, etc., whose heat load is partially or wholly impacted by the operation of the waste heat recovery system.

To demonstrate that a project meets the requirements under this protocol, the project proponent must supply sufficient evidence to demonstrate that:

1. The heat collected was not being used in either a passive or an active manner, where the redistribution of this heat source is not accounted for as supplementary heat under this protocol, as confirmed by an affirmation from the supplier of the waste heat;
2. The implementation of the waste heat recovery project must not materially impact on the operations of the unit (mechanical, biological or chemical) as confirmed by an affirmation from the project proponent and relevant system design records;
3. There is no generation of supplemental heat or power generated off-site under the project condition, as confirmed by an affirmation from the project proponent and relevant system design records;
4. There was no generation of electricity at the project site under the baseline condition as confirmed by an affirmation from the project proponent and relevant system design records;

**FIGURE 1.1: Process Flow Diagram for Project Condition**

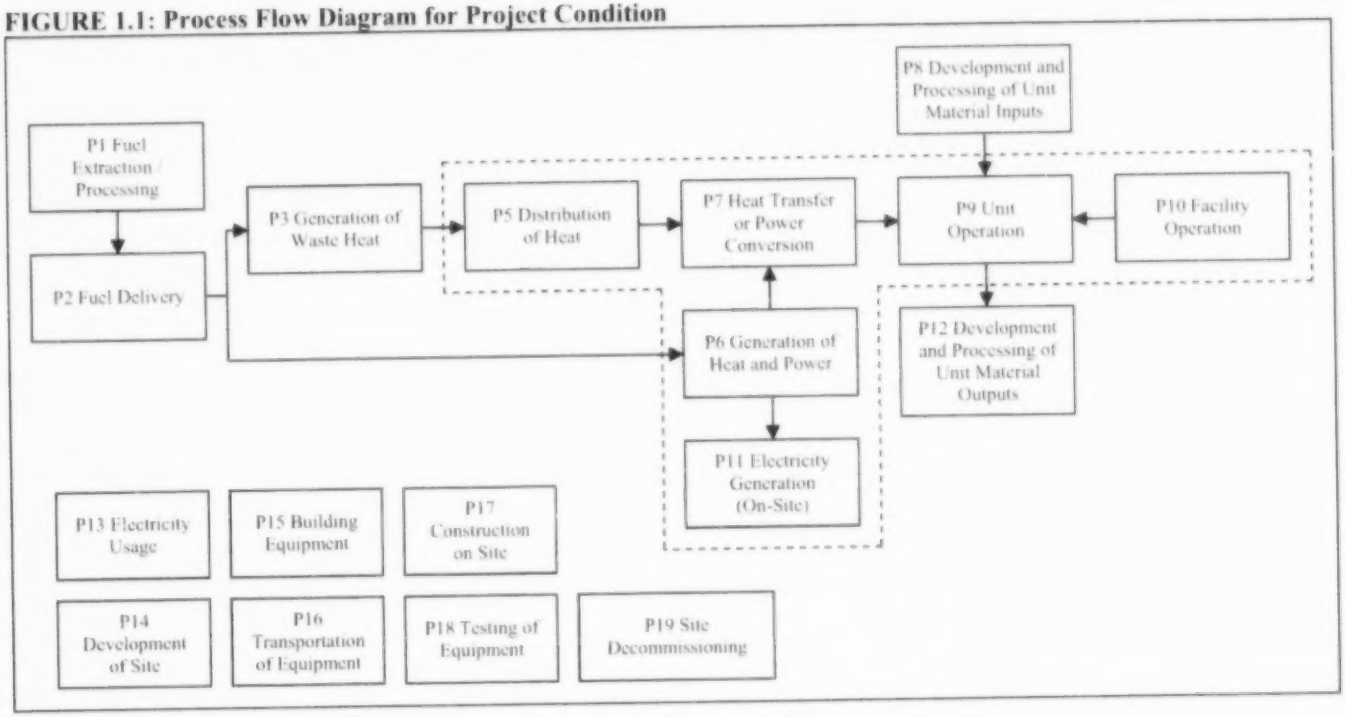
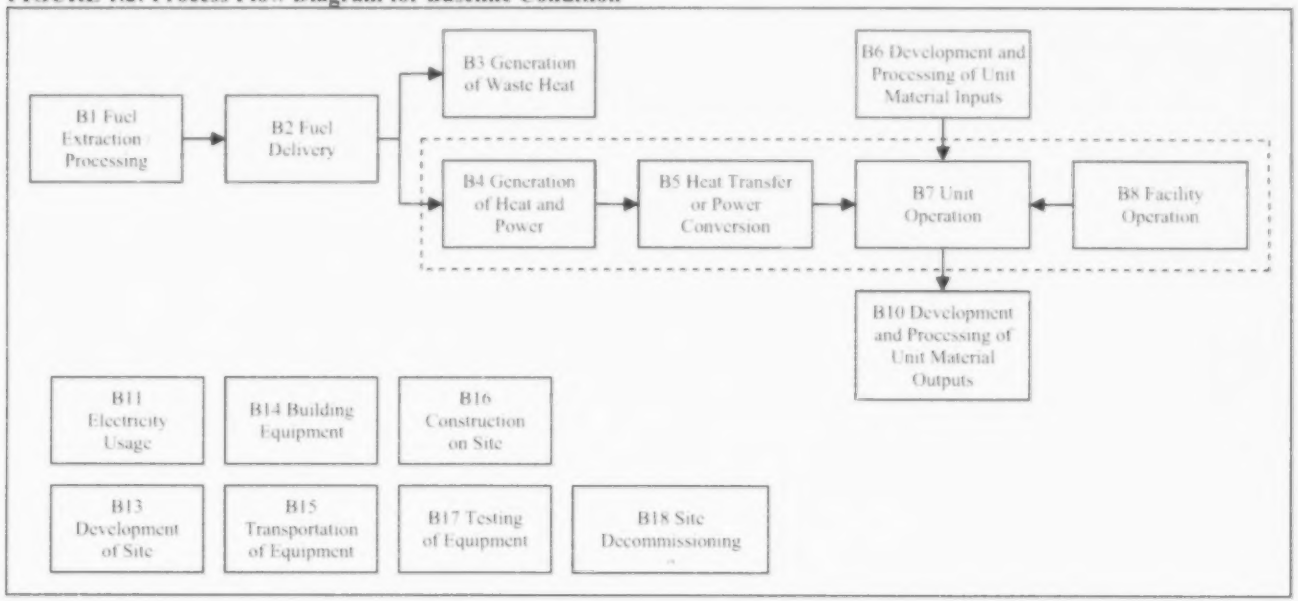

P8 Development and Processing of Unit Material Inputs
P1 Fuel Extraction / Processing
P3 Generation of Waste Heat
P5 Distribution of Heat
P7 Heat Transfer or Power Conversion
P9 Unit Operation
P10 Facility Operation
P2 Fuel Delivery
P6 Generation of Heat and Power
P12 Development and Processing of Unit Material Outputs
P11 Electricity Generation (On-Site)
P13 Electricity Usage
P15 Building Equipment
P17 Construction on Site
P14 Development of Site
P16 Transportation of Equipment
P18 Testing of Equipment
P19 Site Decommissioning

**FIGURE 1.2: Process Flow Diagram for Baseline Condition**


B1 Fuel Extraction / Processing
B2 Fuel Delivery
B3 Generation of Waste Heat
B4 Generation of Heat and Power
B5 Heat Transfer or Power Conversion
B6 Development and Processing of Unit Material Inputs
B7 Unit Operation
B8 Facility Operation
B10 Development and Processing of Unit Material Outputs
B11 Electricity Usage
B13 Development of Site
B14 Building Equipment
B15 Transportation of Equipment
B16 Construction on Site
B17 Testing of Equipment
B18 Site Decommissioning

5. The quantification of reductions achieved by the project is based on actual measurement and monitoring (except where indicated in this protocol) as indicated by the proper application of this protocol; and,
6. The project must meet the requirements for offset eligibility as specified in the applicable regulation and guidance documents for the Alberta Offset System.

Flexibility in applying the quantification protocol is provided to project developers in three ways:

1. The source of the waste heat may supplement their heat demand either to replace a component of the heat being transferred or to augment the heat and power exported, however, these emissions must be captured as supplementary heat and power under this protocol;
2. Waste heat recovery projects may occur within a single site or across multiple sites. Further, the defined unit impacted, both on the recovery and utilization of the waste heat, may include multiple processes, equipment, etc. Definition of the units impacted is to be justified by the project proponent;
3. Site specific emission factors may be substituted for the generic emission factors indicated in this protocol document. The methodology for generation of these emission factors must be sufficiently robust as to ensure reasonable accuracy; and
4. Waste heat recovery projects may provide some or all of the heat and power requirements for the facility. Flexibility is provided in terms of allowing the broadening of the project scope to include existing, new, or retrofit supplementary heating both on and off site to meet the project energy load.

If applicable, the proponent must indicate and justify why flexibility provisions have been used.

This quantification protocol is written for the waste heat recovery project developer or proponent. Some familiarity with, or general understanding of, the operation of these systems is expected.

## 1.2 Glossary of New Terms

| | |
|---|---|
| Unit | The project unit is defined as the equipment, processes and facilities that are being serviced and impacted by the waste heat recovery project. The project unit must be clearly defined and justified by the project proponent. |

# 2.0 QUANTIFICATION DEVELOPMENT AND JUSTIFICATION

The following sections outline the quantification development and justification.

## 2.1 IDENTIFICATION OF SOURCES AND SINKS (SS'S) FOR THE PROJECT

SS's were identified for the project by reviewing the seed protocol document and relevant process flow diagram. This process confirmed that the SS's in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagrams provided in **FIGURE 1.1**, the project SS's were organized into life cycle categories in **FIGURE 2.1**. Descriptions of each of the SS's and their classification as controlled, related or affected are provided in **TABLE 2.1.**

**FIGURE 2.1: Project Element Life Cycle Chart**

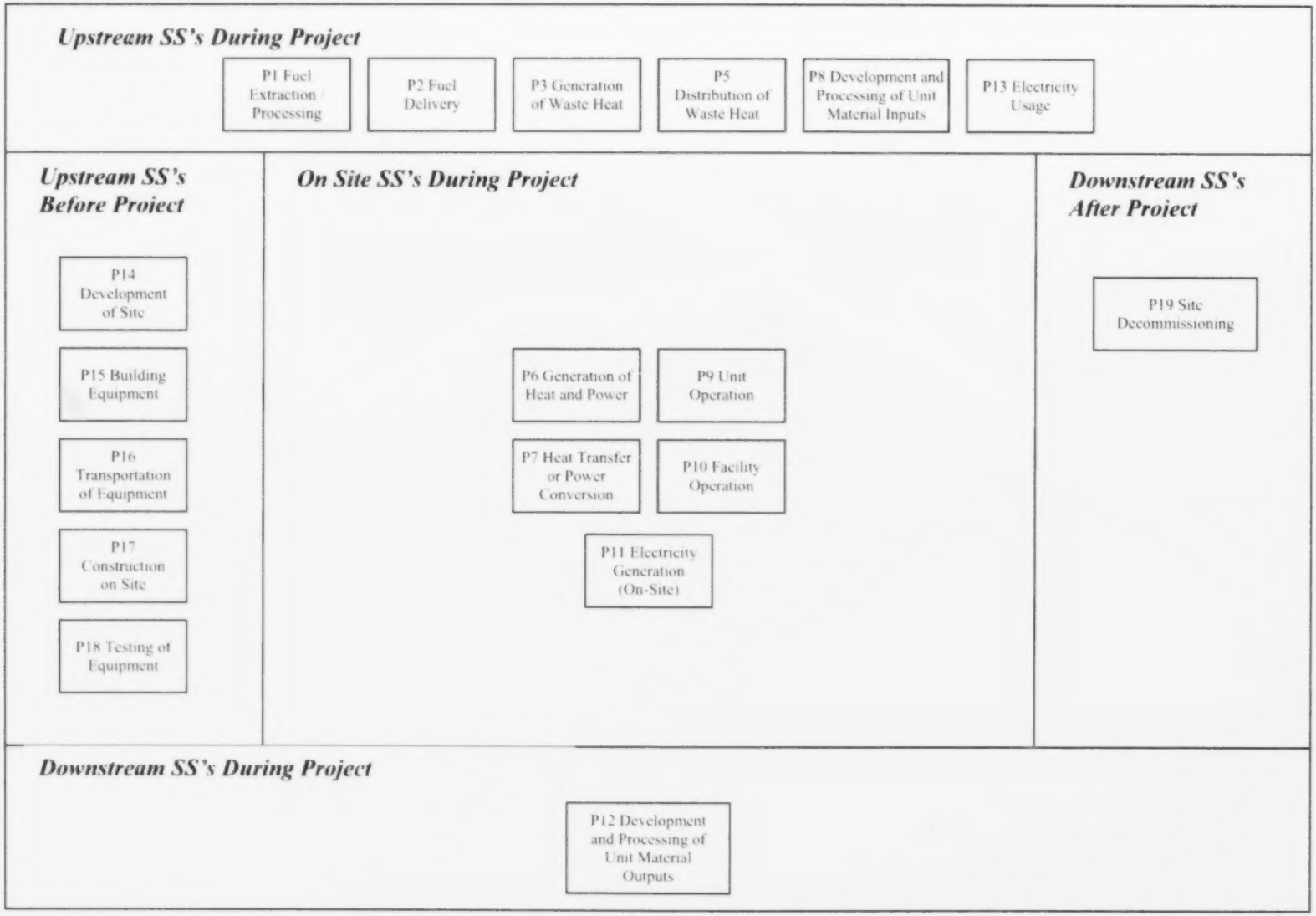

Upstream SS's During Project
P1 Fuel Extraction / Processing
P2 Fuel Delivery
P3 Generation of Waste Heat
P5 Distribution of Waste Heat
P8 Development and Processing of Unit Material Inputs
P13 Electricity Usage
Upstream SS's Before Project
P14 Development of Site
P15 Building Equipment
P16 Transportation of Equipment
P17 Construction on Site
P18 Testing of Equipment
On Site SS's During Project
P6 Generation of Heat and Power
P9 Unit Operation
P7 Heat Transfer or Power Conversion
P10 Facility Operation
P11 Electricity Generation (On-Site)
Downstream SS's After Project
P19 Site Decommissioning
Downstream SS's During Project
P12 Development and Processing of Unit Material Outputs

**TABLE 2.1: Project SS's**

| 1. SS | 2. Description | 3. Controlled, Related or Affected |
|---|---|---|
| **Upstream SS's during Project Operation** | | |
| P1 Fuel Extraction and Processing | Each of the fuels used throughout the project will need to sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked. | Related |
| P2 Fuel Delivery | Each of the fuels used throughout the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the sites is captured under other SS's and there is no other delivery. | Related |
| P3 Generation of Waste Heat | The generation of waste heat may require the combustion of fossil fuels precipitating greenhouse gas emissions. Volumes and types of fuels are the important characteristics to be tracked. | Related |
| P5 Distribution of Waste Heat | The waste heat may need to be distributed to the project site. This may require compression or other mechanical processes and includes any recirculation functions. The energy inputs related to this function would need to be tracked. | Related |
| P8 Development and Processing of Unit Material Inputs | The material inputs to the unit process need to be transported, developed and/or processed prior to the unit process. This may require any number of mechanical, chemical or biological processes. All relevant characteristics of the material inputs would need to be tracked to prove functional equivalence with the baseline scenario. | Related |
| P13 Electricity Usage | Electricity may be required for operating the facility or to compensate for any net reduction in electricity output from the project facility as compared to the baseline. This power may be sourced either from internal generation, connected facilities or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid. Quantity and source of power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions. | Related |
| **Onsite SS's during Project Operation** | | |
| P6 Generation of Heat and Power | The generation of heat and power may be required to supplement the heat delivered to the project site. This generation could require the combustion of fossil fuels precipitating greenhouse gas emissions. Volumes and types of fuels are the important characteristics to be tracked. | Controlled |
| P7 Heat Transfer or Power Conversion | Mechanical or other processes may be required to transfer the heat and power delivered to a usable form at the project site. All relevant characteristics of the heat transfer or power conversion would need to be tracked to prove functional equivalence with the baseline scenario. | Controlled |

| | | |
|---|---|---|
| P9 Unit Operation | Greenhouse gas emissions may occur that are associated with the operation and maintenance of the unit at the project site. This may require any number of mechanical, chemical or biological processes. All relevant characteristics of the material inputs would need to be tracked to prove functional equivalence with the baseline scenario. | Controlled |
| P10 Facility Operation | Greenhouse gas emissions may occur that are associated with the operation and maintenance of the overall facility operations. This may include running vehicles and facilities at the project site. Quantities and types for each of the energy inputs would be tracked. | Controlled |
| P11 Electricity Generation | Electricity may be generated to meet internal project demand or for export from the project site. The generation of this electricity may yield incremental greenhouse gas emissions. Quantities and types for each of the energy inputs would be tracked. | Controlled |
| **Downstream SS's during Project Operation** | | |
| P12 Development and Processing of Unit Material Outputs | The material inputs to the unit process need to be transported, developed and/or processed subsequent to the unit process. This may require any number of mechanical, chemical or biological processes. All relevant characteristics of the material outputs would need to be tracked to prove functional equivalence with the baseline scenario. | Related |
| **Other** | | |
| P14 Development of Site | The site of the facility may need to be developed. This could include civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas, storm water drainage, offices, vent stacks, firefighting water storage lagoons, etc., as well as structures to enclose, support and house the equipment. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc. | Related |
| P15 Building Equipment | Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly. | Related |
| P16 Transportation of Equipment | Equipment built off-site and the materials to build equipment on-site, will all need to be delivered to the site. Transportation may be completed by truck, barge and/or train. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site. | Related |
| P17 Construction on Site | The process of construction at the site will require a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emission from the use of fossil fuels and electricity. | Related |

| | | |
|---|---|---|
| P18 Testing of Equipment | Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity. | Related |
| P19 Site Decommissioning | Once the facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off-site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site. | Related |

## 2.2 IDENTIFICATION OF BASELINE

The baseline condition for projects applying this streamlined protocol is sites where there is currently waste heat that can have a beneficial use under the project condition, which would offset the fulfillment of the heat load requirements through the combustion of fossil fuels. The baseline condition is defined based on the provision of the equivalent heat load as would be required under the project condition to ensure same level of industrial throughput or the same level or service. This is accomplished by applying an energy balance to the generating, distribution and utilization systems.

The approach to quantifying the baseline will be projection based as there are suitable models for the applicable baseline condition that can provide reasonable certainty. The baseline scenario for this protocol is dynamic as the emissions profile for the baseline activities would be expected to change materially relative to fluctuating heat and power supply and demand, as well as other market conditions.

The baseline condition is defined, including the relevant SS's and processes, as shown in **FIGURE 1.2**. More detail on each of these SS's is provided in Section 2.3, below.

## 2.3 IDENTIFICATION OF SS'S FOR THE BASELINE

Based on the process flow diagrams provided in **FIGURE 1.2**, the project SS's were organized into life cycle categories in **FIGURE 2.2**. Descriptions of each of the SS's and their classification as either 'controlled', 'related' or 'affected' is provided in **TABLE 2.2.**

**FIGURE 2.2: Baseline Element Life Cycle Chart**

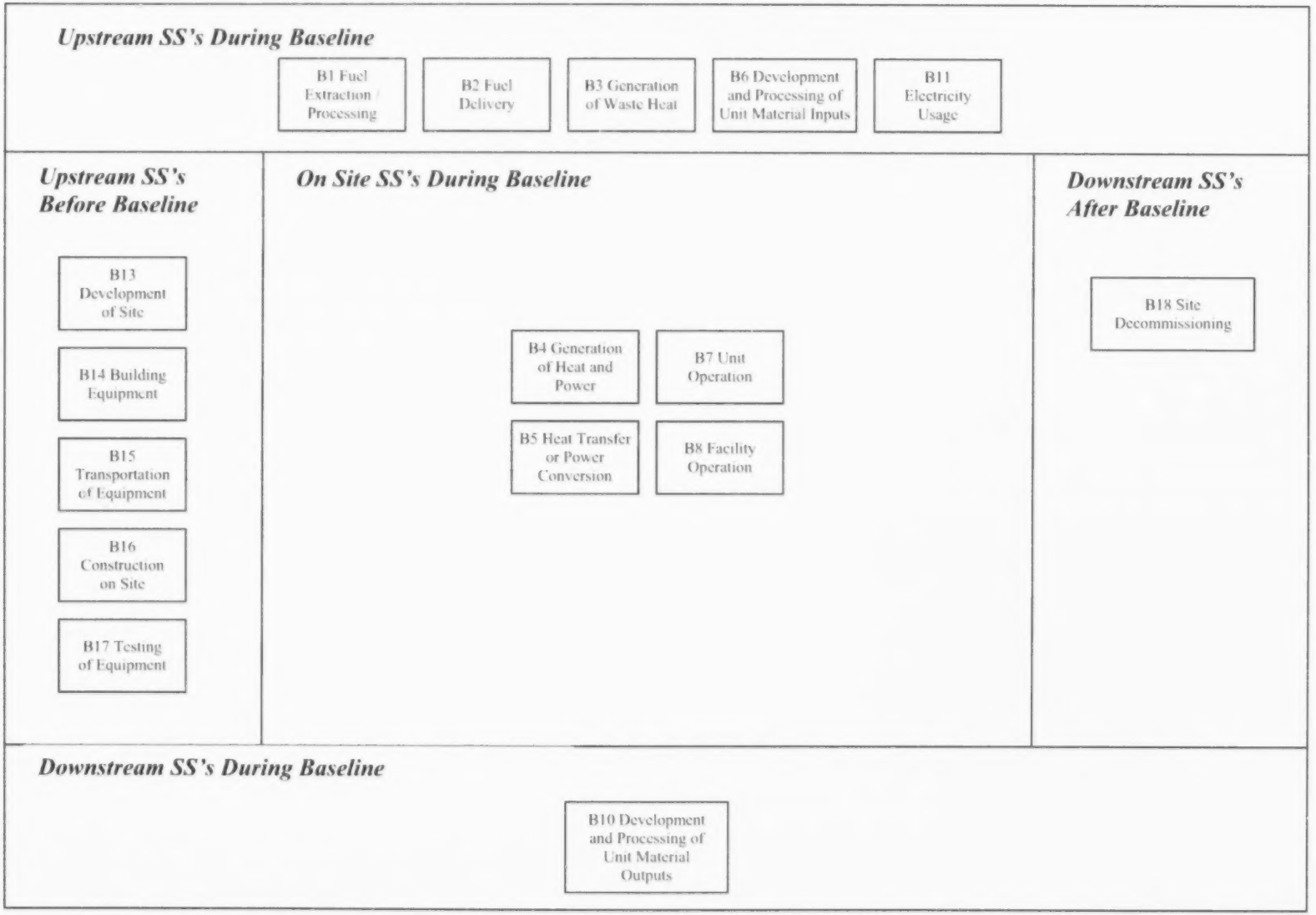

Upstream SS's During Baseline
B1 Fuel Extraction / Processing
B2 Fuel Delivery
B3 Generation of Waste Heat
B6 Development and Processing of Unit Material Inputs
B11 Electricity Usage
Upstream SS's Before Baseline
B13 Development of Site
B14 Building Equipment
B15 Transportation of Equipment
B16 Construction on Site
B17 Testing of Equipment
On Site SS's During Baseline
B4 Generation of Heat and Power
B7 Unit Operation
B5 Heat Transfer or Power Conversion
B8 Facility Operation
Downstream SS's After Baseline
B18 Site Decommissioning
Downstream SS's During Baseline
B10 Development and Processing of Unit Material Outputs

**TABLE 2.2: Baseline SS's**

| 1. SS | 2. Description | 3. Controlled, Related or Affected |
|---|---|---|
| **Upstream SS's during Baseline Operation** | | |
| B1 Fuel Extraction and Processing | Each of the fuels used throughout the project will need to sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked. | Related |
| B2 Fuel Delivery | Each of the fuels used throughout the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the sites is captured under other SS's and there is no other delivery. | Related |
| B3 Generation of Waste Heat | The generation of waste heat may require the combustion of fossil fuels precipitating greenhouse gas emissions. Volumes and types of fuels are the important characteristics to be tracked. | Related |
| B6 Development and Processing of Unit Material Inputs | The material inputs to the unit process need to be transported, developed and/or processed prior to the unit process. This may require any number of mechanical, chemical or biological processes. All relevant characteristics of the material inputs would need to be tracked to prove functional equivalence with the project scenario. | Related |
| B11 Electricity Usage | Electricity may be required for operating the facility or to compensate for any electricity output from the project facility as compared to the baseline. This power may be sourced either from internal generation, connected facilities or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid. Quantity and source of power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions. | Related |
| **Onsite SS's during Baseline Operation** | | |
| B4 Generation of Heat and Power | The generation of heat and power may be required at the project site. This generation could require the combustion of fossil fuels precipitating greenhouse gas emissions. Volumes and types of fuels are the important characteristics to be tracked. | Controlled |
| B5 Heat Transfer or Power Conversion | Mechanical or other processes may be required to transfer the heat and power delivered to a usable form under the baseline condition. All relevant characteristics of the heat transfer or power conversion would need to be tracked to prove functional equivalence with the project scenario. | Controlled |
| B7 Unit Operation | Greenhouse gas emissions may occur that are associated with the operation and maintenance of the unit at the project site. This may require any number of mechanical, chemical or biological processes. All relevant characteristics of the material inputs would need to be tracked to prove functional equivalence with the project scenario. | Controlled |
| B8 Facility Operation | Greenhouse gas emissions may occur that are associated with the operation and maintenance of the overall facility operations. This may include running vehicles and facilities under the baseline condition. Quantities and types for each of the energy inputs would be tracked. | Controlled |

| | | |
|---|---|---|
| **Downstream SS's during Baseline Operation** | | |
| B10 Development and Processing of Unit Material Outputs | The material inputs to the unit process need to be transported, developed and/or processed subsequent to the unit process. This may require any number of mechanical, chemical or biological processes. All relevant characteristics of the material outputs would need to be tracked to prove functional equivalence with the project scenario. | Related |
| **Other** | | |
| B12 Development of Site | The site of the facility may need to be developed. This could include civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas, storm water drainage, offices, vent stacks, firefighting water storage lagoons, etc., as well as structures to enclose, support and house the equipment. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc. | Related |
| B13 Building Equipment | Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly. | Related |
| B14 Transportation of Equipment | Equipment built off-site and the materials to build equipment on-site, will all need to be delivered to the site. Transportation may be completed by truck, barge and/or train. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site. | Related |
| B15 Construction on Site | The process of construction at the site will require a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emission from the use of fossil fuels and electricity. | Related |
| B16 Testing of Equipment | Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity. | Related |
| B17 Site Decommissioning | Once the facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off-site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site. | Related |

## 2.4 SELECTION OF RELEVANT PROJECT AND BASELINE SS'S

Each of the SS's from the project and baseline condition were compared and evaluated as to their relevancy using the guidance provided in Annex VI of the "Guide to Quantification Methodologies and Protocols: Draft", dated March 2006 (Environment Canada). The justification for the exclusion or conditions upon which SS's may be excluded is provided in **TABLE 2.3** below. All other SS's listed previously are included.

**TABLE 2.3: Comparison of SS's**

| 1. Identified SS | 2. Baseline (C, R, A) | 3. Project (C, R, A) | 4. Include or Exclude from Quantification | 5. Justification for Exclusion |
|---|---|---|---|---|
| **Upstream SS's** | | | | |
| P1 Fuel Extraction and Processing | N/A | Related | Include | N/A |
| B1 Fuel Extraction and Processing | Related | N/A | Include | |
| P2 Fuel Delivery | N/A | Related | Exclude | Excluded as the emissions from transportation are likely greater under the baseline condition. |
| B2 Fuel Delivery | Related | N/A | Exclude | |
| P3 Generation of Waste Heat | N/A | Related | Exclude | Excluded as by definition, the generation of this component of the heat is deemed as a waste produced as part of another process. As such, the project and baseline condition are defined to be functionally equivalent. |
| B3 Generation of Waste Heat | Related | N/A | Exclude | |
| P5 Distribution of Waste Heat | Related | N/A | Include | N/A |
| P8 Development and Processing of Unit Material Inputs | N/A | Related | Exclude | Excluded as by definition, must be functionally equivalent to allow for the application of the protocol. |
| B6 Development and Processing of Unit Material Inputs | Related | N/A | Exclude | |
| P13 Electricity Usage | N/A | Related | Exclude | Excluded as these SS's are not relevant to the project as the emissions from these practises are covered under proposed greenhouse gas regulations. |
| B11 Electricity Usage | Related | N/A | Include | Include only the component of electricity production that is offset by the additional generation of electricity by the project. |
| **Onsite SS's** | | | | |
| P6 Generation of Heat and Power | N/A | Controlled | Include | N/A |
| B4 Generation of Heat and Power | Controlled | N/A | Include | |
| P7 Heat Transfer or Power Conversion | N/A | Controlled | Include | N/A |
| B5 Heat Transfer or Power Conversion | Controlled | N/A | Include | |
| P9 Unit Operation | N/A | Controlled | Exclude | Excluded as under the scope of the streamlined waste heat recovery protocol these must be functionally equivalent. |
| B7 Unit Operation | Controlled | N/A | Exclude | |
| P10 Facility Operation | N/A | Controlled | Exclude | Excluded as the facility operation is not typically impacted by the implementation of the project and as such the baseline and project conditions will be functionally equivalent. |
| B8 Facility Operation | Controlled | N/A | Exclude | |

| | | | | |
|---|---|---|---|---|
| P11 Electricity Generation | N/A | Related | Include | N/A |
| **Downstream SS's** | | | | |
| P12 Development and Processing of Unit Material Outputs | N/A | Related | Exclude | Excluded as by definition, these components must be functionally equivalent to allow for the application of the protocol. |
| B10 Development and Processing of Unit Material Outputs | Related | N/A | Exclude | |
| **Other** | | | | |
| P14 Development of Site | N/A | Related | Exclude | Emissions from site development are not material given the long project life, and the minimal site development typically required. |
| B12 Development of Site | Related | N/A | Exclude | Emissions from site development are not material for the baseline condition given the minimal site development typically required. |
| P15 Building Equipment | N/A | Related | Exclude | Emissions from building equipment are not material given the long project life, and the minimal building equipment typically required. |
| B13 Building Equipment | Related | N/A | Exclude | Emissions from building equipment are not material for the baseline condition given the minimal building equipment typically required. |
| P16 Transportation of Equipment | N/A | Related | Exclude | Emissions from transportation of equipment are not material given the long project life, and the minimal transportation of equipment typically required. |
| B14 Transportation of Equipment | Related | N/A | Exclude | Emissions from transportation of equipment are not material for the baseline condition given the minimal transportation of equipment typically required. |
| P17 Construction on Site | N/A | Related | Exclude | Emissions from construction on site are not material given the long project life, and the minimal construction on site typically required. |
| B15 Construction on Site | Related | N/A | Exclude | Emissions from construction on site are not material for the baseline condition given the minimal construction on site typically required. |
| P18 Testing of Equipment | N/A | Related | Exclude | Emissions from testing of equipment are not material given the long project life, and the minimal testing of equipment typically required. |
| B16 Testing of Equipment | Related | N/A | Exclude | Emissions from testing of equipment are not material for the baseline condition given the minimal testing of equipment typically required. |
| P19 Site Decommissioning | N/A | Related | Exclude | Emissions from decommissioning are not material given the long project life, and the minimal decommissioning typically required. |
| B17 Site Decommissioning | Related | N/A | Exclude | Emissions from decommissioning are not material for the baseline condition given the minimal decommissioning typically required. |

## 2.5 QUANTIFICATION OF REDUCTIONS, REMOVALS AND REVERSALS OF RELEVANT SS's

### 2.5.1 Quantification Approaches

Quantification of the reductions, removals and reversals of relevant SS's for each of the greenhouse gases will be completed using the methodologies outlined in **TABLE 2.4**, below. These calculation methodologies serve to complete the following three equations for calculating the emission reductions from the comparison of the baseline and project conditions.

$$\text{Emission Reduction} = \text{Emissions}_{\text{Baseline}} - \text{Emissions}_{\text{Project}}$$

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Fuel Extraction / Processing}} + \text{Emissions}_{\text{Gen Heat and Power}} + \text{Emissions}_{\text{Transfer / Conversion}} + \text{Emissions}_{\text{Electricity Usage}}$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{Fuel Extraction / Processing}} + \text{Emissions}_{\text{Distribute Heat}} + \text{Emissions}_{\text{Gen Heat and Power}} + \text{Emissions}_{\text{Transfer / Conversion}} + \text{Emissions}_{\text{Electricity Generation}}$$

Where:

$\text{Emissions}_{\text{Baseline}}$ = sum of the emissions under the baseline condition.

- $\text{Emissions}_{\text{Fuel Extraction / Processing}}$ = emissions under SS B1 Fuel Extraction and Processing
- $\text{Emissions}_{\text{Gen Heat and Power}}$ = emissions under SS B4 Generation of Heat and Power
- $\text{Emissions}_{\text{Transfer / Conversion}}$ = emissions under SS B5 Heat Transfer or Power Conversion
- $\text{Emissions}_{\text{Electricity Usage}}$ = emissions under SS B11 Electricity Usage

$\text{Emissions}_{\text{Project}}$ = sum of the emissions under the project condition.

- $\text{Emissions}_{\text{Fuel Extraction / Processing}}$ = emissions under SS P1 Fuel Extraction and Processing
- $\text{Emissions}_{\text{Distribute Heat}}$ = emissions under SS P5 Distribution of Waste Heat
- $\text{Emissions}_{\text{Gen Heat and Power}}$ = emissions under SS P6 Generation of Heat and Power
- $\text{Emissions}_{\text{Transfer / Conversion}}$ = emissions under SS P7 Heat Transfer or Power Conversion
- $\text{Emissions}_{\text{Elec Gen}}$ = emissions under SS P11 Electricity Generation

**TABLE 2.4: Quantification Procedures**

| 1. Project / Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|---|---|---|---|---|---|---|
| **Project SS's** | | | | | | |
| P1 Fuel Extraction and Processing | $Emissions_{Fuel\ Extraction\ /\ Processing} = \sum (Vol.\ Fuel_i * EF\ Fuel_{i,CO2}) ; \sum (Vol.\ Fuel_i * EF\ Fuel_{i,CH4}) ; \sum (Vol.\ Fuel_i * EF\ Fuel_{i,N2O})$ | | | | | |
| | $Emissions_{Fuel\ Extraction\ /\ Processing}$ | kg of CO2e | N/A | N/A | N/A | Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregated for each of these SS's. |
| | Volume of Fuel Combusted for P4 and P6 / Vol. Fuel | L, $m^3$ or other | Measured | Direct metering or reconciliation of volume in storage (including volumes received). | Continuous metering or monthly reconciliation. | Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence. |
| | $CO_2$ Emissions Factor for Fuel Including Production and Processing / $EF\ Fuel_{CO2}$ | kg $CO_2$ per L, $m^3$ or other | Estimated | From Environment Canada or CAPP reference documents. | Annual | Reference values. |
| | $CH_4$ Emissions Factor for Fuel Including Production and Processing / $EF\ Fuel_{CH4}$ | kg $CH_4$ per L, $m^3$ or other | Estimated | From Environment Canada or CAPP reference documents. | Annual | Reference values. |
| | $N_2O$ Emissions Factor for Fuel Including Production and Processing / $EF\ Fuel_{N2O}$ | kg N2O per L, $m^3$ or other | Estimated | From Environment Canada or CAPP reference documents. | Annual | Reference values. |
| P5 Distribution of Waste Heat | $Emissions_{Distribute\ Heat\ and\ Power} = \sum (Vol.\ Fuel_i * EF\ Fuel_{i,CO2}); \sum (Vol.\ Fuel_i * EF\ Fuel_{i,CH4}) ; \sum (Vol.\ Fuel_i * EF\ Fuel_{i,N2O})$ | | | | | |
| | $Emissions_{Distribute\ Heat\ and\ Power}$ | kg of $CO_2$ ; $CH_4$ ; $N_2O$ | N/A | N/A | N/A | Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregated for each of these SS's. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Volume of Each Type of Fuel Combusted for the Distribution of Waste Heat / Vol. Fuel $_i$ | L, $m^3$ or other | Measured | Direct metering or reconciliation of volume in storage (including volumes received). | Continuous metering or monthly reconciliation. | Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence. |
| | $CO_2$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,CO2}$ | kg $CO_2$ per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | $CH_4$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,CH4}$ | kg $CH_4$ per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | $N_2O$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,N2O}$ | kg N2O per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| P6 Generation of Heat and Power | Emissions $_{Gen\ Heat\ and\ Power} = \sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,CO2}$); $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,CH4}$) ; $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,N2O}$) | | | | | |
| | Emissions $_{Gen\ Heat\ and\ Power}$ | kg of $CO_2$ ; $CH_4$ ; $N_2O$ | N/A | N/A | N/A | Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregated for each of these SS's. |
| | Volume of Each Type of Fuel Consumed to Generate Heat and Power / Vol. Fuel $_i$ | L, $m^3$ or other | Measured | Direct metering or reconciliation of volume in storage (including volumes received). | Continuous metering or monthly reconciliation. | Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence. |
| | $CO_2$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,CO2}$ | kg $CO_2$ per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | $CH_4$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,CH4}$ | Kg $CH_4$ per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | $N_2O$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,N2O}$ | kg N2O per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| P7 Heat Transfer or Power Conversion | Emissions $_{Transfer\ Conversion} = \sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,CO2}$); $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,CH4}$) ; $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,N2O}$) | | | | | |
| | Emissions $_{Transfer\ Conversion}$ | kg of $CO_2$ ; $CH_4$ ; $N_2O$ | N/A | N/A | N/A | Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregated for each of these SS's. |
| | Volume of Each Type of Fuel Consumed for Heat Transfer or Power Conversion / Vol. Fuel $_i$ | L, $m^3$ or other | Measured | Direct metering or reconciliation of volume in storage (including volumes received). | Continuous metering or monthly reconciliation. | Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence. |
| | $CO_2$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,CO2}$ | kg $CO_2$ per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | $CH_4$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,CH4}$ | Kg $CH_4$ per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | $N_2O$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,N2O}$ | kg N2O per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| P11 Electricity Generation | Emissions $_{Elec\ Gen} = \sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,CO2}$); $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,CH4}$) ; $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,N2O}$) | | | | | |
| | Emissions $_{Elec\ Gen}$ | kg of $CO_2$ ; $CH_4$ ; $N_2O$ | N/A | N/A | N/A | Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregated for each of these SS's. |
| | Volume of Each Type of Fuel for Electricity Generation / Vol. Fuel $_i$ | L, $m^3$ or other | Measured | Direct metering or reconciliation of volume in storage (including volumes received). | Continuous metering or monthly reconciliation. | Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | $CO_2$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,CO2}$ | kg $CO_2$ per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | $CH_4$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,CH4}$ | kg $CH_4$ per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | $N_2O$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,N2O}$ | kg N2O per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| **Baseline SS's** | | | | | | |
| B1 Fuel Extraction and Processing | Emissions $_{Fuel\ Extraction\ -\ Processing}$ = $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,CO2}$) ; $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,CH4}$) ; $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,N2O}$) | | | | | |
| | Emissions $_{Fuel\ Extraction\ -\ Processing}$ | kg of CO2e | N/A | N/A | N/A | Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregated for each of these SS's. |
| | Volume of Fuel Combusted for B4 / Vol. Fuel | L, $m^3$ or other | Estimated | Based on equivalent heat and power demand with the most likely fuel. | Monthly | Represents most reasonable means of estimation. |
| | $CO_2$ Emissions Factor for Natural Gas / EF Fuel $_{CO2}$ | kg $CO_2$ per L, $m^3$ or other | Estimated | From Environment Canada or CAPP reference documents. | Annual | Reference values. |
| | $CH_4$ Emissions Factor for Natural Gas / EF Fuel $_{CH4}$ | kg $CH_4$ per L, $m^3$ or other | Estimated | From Environment Canada or CAPP reference documents. | Annual | Reference values. |
| | $N_2O$ Emissions Factor for Natural Gas / EF Fuel $_{N2O}$ | kg N2O per L, $m^3$ or other | Estimated | From Environment Canada or CAPP reference documents. | Annual | Reference values. |
| B4 Generation of Heat and Power | Emissions $_{Gen\ Heat\ and\ Power}$ = $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,CO2}$); $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,CH4}$) ; $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,N20}$) | | | | | |
| | Emissions $_{Gen\ Heat\ and\ Power}$ | kg of $CO_2$ ; $CH_4$ ; $N_2O$ | N/A | N/A | N/A | Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregated for each of these SS's. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Volume of Each Type of Fuel Consumed to Generate Heat and Power / Vol. Fuel $_i$ | L, $m^3$ or other | Estimated | Based on equivalent heat and power demand with the most likely fuel. | Monthly | Represents most reasonable means of estimation. |
| | $CO_2$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,CO2}$ | kg $CO_2$ per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | $CH_4$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,CH4}$ | kg $CH_4$ per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | $N_20$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,N2O}$ | kg N2O per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| B5 Heat Transfer or Power Conversion | Emissions $_{Transfer / Conversion}$ = $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,CO2}$); $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,CH4}$) ; $\sum$ (Vol. Fuel $_i$ * EF Fuel $_{i,N20}$) | | | | | |
| | Emissions $_{Transfer / Conversion}$ | kg of $CO_2$ ; $CH_4$ ; $N_2O$ | N/A | N/A | N/A | Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregated for each of these SS's. |
| | Volume of Each Type of Fuel Consumed for Heat Transfer or Power Conversion / Vol. Fuel $_i$ | L, $m^3$ or other | Estimated | Based on equivalent heat and power demand with the most likely fuel. | Monthly | Represents most reasonable means of estimation. |
| | $CO_2$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,CO2}$ | kg $CO_2$ per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | $CH_4$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,CH4}$ | kg $CH_4$ per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| | $N_2O$ Emissions Factor for Combustion of Each Type of Fuel / EF Fuel $_{i,N2O}$ | kg N2O per L, $m^3$ or other | Estimated | From Environment Canada reference documents. | Annual | Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory. |
| B11 Electricity Usage | Emissions $_{Electricity}$ = Electricity * EF $_{Elec}$ | | | | | |
| | Emissions $_{Electricity}$ | kg of CO2e | N/A | N/A | N/A | Quantity being calculated. |
| | Net Electricity Exported from the Site / Electricity | kWh | Measured | Direct metering. | Continuous metering | Continuous direct metering represents the industry practise and the highest level of detail. |
| | Emissions Factor for Electricity / EF $_{Elec}$ | kg of CO2e per kWh | Estimated | From Alberta Environment reference documents. | Annual | Reference values adjusted as appropriate by Alberta Environment. |

### 2.5.2. Contingent Data Approaches

Contingent means for calculating or estimating the required data for the equations outlined in section 2.5.1 are summarized in **TABLE 2.5**, below.

## 2.6 MANAGEMENT OF DATA QUALITY

In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data should be of sufficient quality to fulfill the quantification requirements and be substantiated by company records for the purpose of verification.

The project proponent shall establish and apply quality management procedures to manage data and information. Written procedures should be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily an audit will be to conduct for the project.

### 2.6.1 Record Keeping

Record keeping practises should include:

a. Electronic recording of values of logged primary parameters for each measurement interval;
b. Printing of monthly back-up hard copies of all logged data;
c. Written logs of operations and maintenance of the project system including notation of all shut-downs, start-ups and process adjustments;
d. Retention of copies of logs and all logged data for a period of 7 years; and
e. Keeping all records available for review by a verification body.

### 2.6.1 Quality Assurance/Quality Control (QA/QC)

QA/QC can also be applied to add confidence that all measurements and calculations have been made correctly. These include, but are not limited to:

a Protecting monitoring equipment (sealed meters and data loggers);
b Protecting records of monitored data (hard copy and electronic storage);
c Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records);
d Comparing current estimates with previous estimates as a 'reality check';
e Provide sufficient training to operators to perform maintenance and calibration of monitoring devices;
f Establish minimum experience and requirements for operators in charge of project and monitoring; and

g Performing recalculations to make sure no mathematical errors have been made.

**TABLE 2.5: Contingent Data Collection Procedures**

| 1. Project / Baseline SS | 2. Parameter / Variable | 3. Unit | 4. Measured / Estimated | 5. Contingency Method | 6. Frequency | 7. Justify measurement or estimation and frequency |
|---|---|---|---|---|---|---|
| **Project SS's** | | | | | | |
| P1 Fuel Extraction and Processing | Volume of Each Type of Fuel / Vol $Fuel_i$ | L, $m^3$ or other | Measured | Reconciliation of volume of fuel purchased within given time period. | Monthly | Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used. |
| P5 Distribution of Waste Heat | Volume of Each Type of Fuel / Vol $Fuel_i$ | L, $m^3$ or other | Measured | Reconciliation of volume of fuel purchased within given time period. | Monthly | Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used. |
| P6 Generation of Heat and Power | Volume of Each Type of Fuel / Vol $Fuel_i$ | L, $m^3$ or other | Measured | Reconciliation of volume of fuel purchased within given time period. | Monthly | Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used. |
| P7 Heat Transfer or Power Conversion | Volume of Each Type of Fuel / Vol $Fuel_i$ | L, $m^3$ or other | Measured | Reconciliation of volume of fuel purchased within given time period. | Monthly | Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used. |
| P11 Electricity Generation | Volume of Each Type of Fuel for Electricity Generation / Vol. $Fuel_i$ | L, $m^3$ or other | Measured | Reconciliation of volume of fuel purchased within given time period. | Monthly | Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used. |
| **Baseline SS's** | | | | | | |
| B1 Fuel Extraction and Processing | Volume of Each Type of Fuel / Vol $Fuel_i$ | L, $m^3$ or other | Measured | Reconciliation of volume of fuel purchased within given time period. | Monthly | Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used. |
| B4 Generation of Heat and Power | Volume of Each Type of Fuel / Vol $Fuel_i$ | L, $m^3$ or other | Estimated | Based on equivalent heat and power demand forecast based on typical output. | Monthly | Represents another reasonable means of estimation. |
| B5 Heat Transfer or Power Conversion | Volume of Each Type of Fuel / Vol $Fuel_i$ | L, $m^3$ or other | Estimated | Based on equivalent heat and power demand forecast based on typical output. | Monthly | Represents another reasonable means of estimation. |

| | | | | | | |
|---|---|---|---|---|---|---|
| B11 Electricity Usage | Net Electricity Exported from the Site / Electricity | kWh | Measured | Reconciliation of power requirements for facility as per equipment output ratings. | Monthly | Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used. |

# APPENDIX A:
# EMISSION FACTORS FOR PRODUCTION AND PROCESSING

## EMISSION FACTORS FOR FUEL PRODUCTION AND PROCESSING

All values interpreted from volume 1 of the technical report: A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H2S) Emissions by the Upstream Oil and Gas Industry dated September 2004 completed by Clearstone Engineering Ltd. on behalf of the Canadian Association of Petroleum Producers (CAPP).

**Table A1: Emission Factors for Gasoline and Diesel Production**

| | Approximate Proportionate Amount in Year of Emission Factor Generation | | Emission Factors | | | |
|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | Units |
| **Light / Medium Crude Oil Production** | 55,588 | $10^3$ $m^3$ / yr | 86.3 | 4.41 | 0.0038 | t / $10^3$ $m^3$ |
| **Heavy Crude Oil Cold Production** | 30,924 | $10^3$ $m^3$ / yr | 75 | 25.1 | 0.0033 | t / $10^3$ $m^3$ |
| **Heavy Crude Oil Thermal Production** | 10,589 | $10^3$ $m^3$ / yr | 594.2 | 3.75 | 0.009 | t / $10^3$ $m^3$ |
| **Weighted Average** | | | 0.1381 | 0.0109 | 4.208E-6 | kg / L |

**Table A2: Emission Factors for Natural Gas Production and Processing**

| | Emission Factors | | | |
|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | Units |
| **Natural Gas Production** | 0.0427 | 0.00234 | 0.000004 | kg / $m^3$ |
| **Natural Gas Processing** | 0.0904 | 0.00029 | 3.2E-06 | kg / $m^3$ |